The Iowa River Bridge team pushed the limits of conventional construction techniques to provide a bridge that is beautiful, cost effective, and constructed without compromising the surrounding environment.

IOWA

A Landmark Launch

U.S. 20 IOWA RIVER BRIDGE: AN INDUSTRY CHANGING SOLUTION

The construction of the U.S. 20 Iowa River Bridge represented a landmark in the United States, as it was the first time an incremental launching method was used to erect a steel I-girder highway bridge. At the time of construction, it was also the longest total-launched steel bridge and the longest free cantilever in U.S. history.

The incremental launching method was developed by Fritz Leonhardt in the early 1960s for use with precast-concrete box-girder bridges and has been used for years for erection of more torsionally stable concrete box structures in Europe. It had also been used for a smaller steel box girder railroad bridge in the U.S.

“The Iowa River Bridge pushed the limits of conventional construction techniques,” according to Dan Timmons, Vice President of Jensen Construction, the construction firm for the project. “It provides the State of Iowa and the local community with a bridge that is aesthetically pleasing, cost-effective, and constructed without compromising the surrounding environment,” said Timmons.

The project also represents extraordinary examples of environmental stewardship and a public and private partnership that pushed the envelope of conventional structural engineering principles to achieve an industry-changing solution. “From an engineering standpoint,” Iowa DOT (IDOT) Chief Structural Engineer Ahmad Abu-Hawash said, “the Iowa River Bridge was not just a structural challenge; it required innovative aesthetic, geotechnical, hydraulic and environmental solutions as well.” According to Abu-Hawash, use of the launching method did not increase construction time and it was deemed the best engineering option for making this bridge a reality.

It took some of the nation’s most innovative design and construction methods to achieve the project’s main objective of treading as gently as possible through this sensitive area. Since Iowa’s bridge was built, a similarly launched I-girder bridge has been constructed near Moorefield, West Virginia and other States have shown great interest in the engineering techniques used in the project.

The innovations from the U.S. 20 Iowa River Bridge Project elevate it as a sterling example of the Federal Highway Administration's Highways for LIFE principles.

Driving the Construction Decision: Environmental Sensitivity and Economics

The Iowa River Bridge is sited on 10 acres in the Iowa River Greenbelt, a rare, remaining fragment of old-growth woodland that survived the age of agriculture. The region features a steep river valley rich with traces of prehistoric cultures and remnants of 19th century farmsteads. It is a roosting and wintering area for bald eagles, and home for the rare northern monkshood plant and three endangered or threatened species of freshwater mussels, which are very sensitive to changes in the temperature and clarity of the river in which they live.

Throughout the initial environmental study in 1968 and a number of additional ones, residents and environmental groups were vocal about their desire to preserve the site's natural and historical resources. This environmental sensitivity, along with economics, became part of the overarching design directives of IDOT.

After IDOT hired HNTB Corporation in 1994 to perform the preliminary design, a number of bridge types were evaluated. IDOT wanted a low-profile structure to minimize the visual impact on this scenic area. The steel I-girder bridge type was selected in 1996, and the incremental launching method was determined the only feasible way to construct the bridge while minimizing the environmental impact to the valley. Without this method, crews would have needed to construct temporary erection towers and erect the bridge's structural steel piece-by-piece, working across the environmentally sensitive area.

The incremental launching method offers a number of benefits including minimal disturbance to surrounding areas; it requires a smaller, but more concentrated area for erection; and it increases worker safety since all erection work is performed at a lower elevation.

The total cost of the Iowa River Bridge Project was just under $21 million, which is more than it would have cost with standard bridge construction. Of this amount, 15 to 20 percent of the costs can be directly attributed to design and detailing considerations added to accommodate the environmental concerns and site accessibility challenges. But the costs to the history and environment of using standard bridge construction techniques were incalculable in the public's eye, so the investment to save these precious resources was deemed a cost effective investment. The structure blends so carefully into its natural setting that today, when Iowans canoe under the bridge, they scarcely notice it looming above.

Pushing the Limits of Conventional Construction Techniques

The incrementally launched erection of the Iowa River Bridge consisted of a series of steps with engineering precision figuring in the entire process. First, the contractor erected all the structural steel for the first 505 feet of the east-bound bridge (including girders, diaphragms and upper and lower lateral bracing) on temporary pile bents behind the east abutment in a launching pit. Next, the launching nose (leading end) and tail section (trailing end) were attached to the girder train. The assembled structural steel was then jacked forward longitudinally 302 feet from Pier 6 to Pier 5. The tail section was then removed so additional girder sections could be spliced into place, followed by reinstalling the tail section. Next, the girder was jacked longitudinally to Pier 4. This sequence would be repeated for a total of five spans. Following completion of the eastbound bridge, the launching system was disassembled and reused to launch the westbound bridge in the same fashion.

The Iowa River Bridge consists of two parallel deck superstructures, each of which has five equal spans of nearly 302 feet. In addition, a 62 foot prestressed concrete jump span is located on either end of the steel units. The I-shaped bridge girders are built-up components fabricated from ASTM A709 Grade 50W steel. The girder webs are 11.33 feet deep and the girder lines spaced at 11.81 feet. The designer selected the section depth not based on strength requirements, but to reduce dead-load deflection during launching to a reasonable level. Since any point along the girder length could become a bearing location during launching operations, the constant 0.88 of an inch web thickness was intended to serve as an unstiffened bearing element for steel dead load.

To make the I-girder superstructure act as much like a torsionally rigid box girder as possible during launching, a stiff system of diaphragms and lateral bracing was used. A diaphragm spacing of 23 feet was used for spans two through five, but was reduced to 11 feet, 6 inches in the leading span that would be cantilevered during launching. Also, a system of center-bay upper and lower lateral bracing, composed of WT sections up to 76 lb/ft, formed the "spine" of the girder system. In the leading two panels of the girder system, additional lateral bracing was provided in the outer girder bays as well. The stiff spine, however, did cause some concern following launching of the steel girder units when it was determined that when the girders reached their final position, a gap of up to 1/2 inch between the bearing and bottom flange existed. To solve the problem, crews fitted these gap locations with steel shim plates to fill the gap and preload the bearing, so all girder reactions were uniform at a given pier.

Although not part of the bridge that was launched, the concrete slab deck consisted of a 9 inch concrete slab with a 1 ½ inch low-slump concrete wearing surface. A high-performance concrete mix was used for the deck to minimize the potential for shrinkage and cracking.

The bridge foundations are 100 ton steel H-pile foundations driven to rock at Piers 1, 2 and 5 and 100 ton steel H-piles driven to refusal in clay at Pier 6. To minimize the footprint of the pier foundations near the river, Piers 3 and 4 were founded on 8 foot diameter drilled shafts approximately 98 feet deep.

Launch: All Systems Go

The actual launching system used to construct the Iowa River Bridge was designed by the erection engineer, Ashton Engineering of Davenport, Iowa. It allowed the use of equipment already owned by the prime contractor, Jensen Construction, and the rollers and other equipment were fabricated or modified by Jensen engineers for the project.

The launch system included a launch pit that was a prepared working area approximately 660 feet by 120 feet by 20 feet that could accommodate the construction, at grade, of an approximate superstructure length of 500 feet prior to launching. This launching pit was located in line with the eventual approach roadway and one of the short pre-stressed concrete jump-spans in the project plans. For environmental purposes, the contractor was required to confine all storm water to three intakes in the center of the launching pit. A series of six temporary pile bents were constructed in the launching pit, four of which were equipped with vertical and horizontal rollers to support and guide

Aerial view of launching pit that accommodated the construction, at grade, of an approximate superstructure length of 500 feet prior to launching.

the girders during launching operations. The remaining two bents did not have rollers and were used to provide temporary support during steel girder assembly operations.

A total of four vertical bearing rollers equipped with bronze and fiber bushings were placed on the four temporary roller bents in the launching pit as well as on the six permanent bridge piers. These were aligned with the centerline of the girders to allow them to move longitudinally during launching.

The structural steel was completely erected on the temporary pile bents; all bolts were tightened; and a bridge drainage piping system was installed prior to launching the girder train. The drainage system consisted of two 14 inch pipes running the length of each superstructure unit. As a result, storm water and runoff could not directly enter the river, another of the many environmental efforts of the project to protect the habitat.

The leading end of the steel girder unit was equipped with a tapered launching nose that consisted of a pair of tapered I-girders bolted to the leading end of the permanent interior girders. The nose was approximately 146 feet long, and tapered from 11 feet deep at the connection to the permanent girders to 4 feet deep at the tip. The primary purpose of the nose was to touch down on top of the landing pier rollers and then recover or lift the permanent girders upward into position as the girders continued to be launched forward longitudinally. The reduced weight of the two tapered girders considerably reduced the superstructure bending moments as well as the cantilever deflection of the leading span. By design, the dead load deflection of the leading span was accommodated by the tapered form of the launching nose.

The trailing end of the unit had a 27 foot, 6 inch tail section consisting of a four-girder assembly bolted to the trailing end of the girder train. This trailing assembly provided a dapped seat 5 feet wide by 6 feet, 8 inches deep. The tail also served two purposes: it afforded a location to apply the jacking force to the rear of the girder lines; the tapered shape (6:1 ratio) enabled a smooth transition as the trailing end of the girders dropped off the roller supports in the pit and the girders were launched forward. The dapped end of the tail supported a transverse tugger beam consisting of two W36x150 sections welded tip-to-tip with 2 ½ inch cover plates.

Two groups of battered-steel H-piles located near the east end of the launching pit supported the jacking system used to launch the steel unit. Each pile group supported a 152 ton hydraulic ram that was oriented parallel and adjacent to the exterior girder. Each of these jacks was attached to a line of 2 ½ inch, 150 ksi post-tensioning bars that were spliced at 15 foot intervals. The dead end of the bar was anchored to a transverse tugger beam that was supported on the dapped end of the tail section at the trailing end of the girders. Each launching cycle consisted of extending the hydraulic jacks to a 15-foot stroke, releasing jacking force on the jack, uncoupling and removing a section of PT bar from each line, retracting the jacks, reconnecting the PT bars, and beginning the next cycle. This procedure was duplicated approximately 20 times until the superstructure was seated on the next pier.

For the bolted girder splices to negotiate the bearing rollers, a tapered (6:1 ratio) ramp plate was installed at the leading and trailing edge of each splice. During launching, each time a ramp plate would encounter a roller, a measurable increase in jacking force occurred. This additional energy was released as a girder "lunge" as the ramp plate was cleared and rollers returned to the flat region of the flange.

Launch operations were not allowed when wind speed could exceed twenty miles per hour within a twelve hour period. As a result, two of the ten launch events were postponed because of wind speeds. The steel girders were launched in one-span increments in order to minimize the exposure time of the free cantilever.

The ten launches of the U.S. 20 Iowa River Bridge were performed at two-to-three week intervals between August, 2001 and March, 2002. Following completion of the eastbound bridge launching in October, 2001, the temporary pile bents were removed and reinstalled for use in launching the westbound bridge beginning in January 2002.

Lessons Learned: An Engineer's Perspective

Based on the results of the monitoring study performed by the Iowa State University Bridge Engineering Center, *Monitoring of the Launched Girder Bridge over the Iowa River on U.S. 20, Final Report*, a number of recommendations were made for consideration on future launched bridge projects. Key recommendations are listed below, however, a wealth of information and suggestions are also contained in the study:

- Use a constant width bottom flange for all launched I-girders in an effort to eliminate the need for an adjustable guide roller on the bottom flange. The lateral force necessary to maintain the proper alignment of the girders during launching is considerable and requires a substantial guide roller system. If the girder alignment cannot be maintained within tight tolerance, there is potential for serious damage to the girder system during launching operations.
- Use a larger diameter single bearing roller or a series of smaller diameter bearing rollers to distribute the concentrated load over a much larger area of the bottom flange.
- If possible, mount the launching rollers to the girders so they are continuously supported to reduce launch induced stresses.
- Provide pre-cast anchor bolt wells in the concrete capbeam (like those used on the Iowa River Bridge project) in an effort to provide the contractor some additional tolerance for the final position of the steel superstructure.

- Design crossframe members, girders and connections to be able to support the weight of one girder supported only by the crossframe connections to the adjacent girder.
- Develop a launching system that is reversible so that the contractor has the option to retract the cantilevered girders in the event of an unexpected problem.

Engineering Around Community and Culture

The local residents of the Hardin County area showed overwhelming interest in the Iowa River Bridge project since the first public meetings were held in the mid-1990s. In fact, many had been waiting for this project to be completed for more than 30 years. To keep the public informed, IDOT held an open house after the first few launches to allow the public an up-close look at the project; more than 2000 people attended, far more than were expected from this lightly populated area.

After the project was completed, the Hardin County Conservation Board made plans to construct a viewing area with a distinctive memorial plaque to honor the men and women who built the unique crossing over the Iowa River. The honor will recognize the unprecedented environmental mitigation methods used before, during and after the construction.

Because the area is the preferred habitat for at least three rare species of freshwater mussels, contract documents included strict environmental limitations. The use of causeways or temporary bridges to cross the river was prohibited. The contractor was also required to provide containment for heavy equipment in the event that a spill were to occur, and remove all drilling spoils, including artesian water, from the contractually-defined Environmentally Sensitive Work Zone (ESWZ). IDOT also kept at hand a number of spill kits which contained absorbent materials and floating booms.

Coincident to the construction site is a small valley with an east-west orientation that is sheltered from the coldest northwest winds and snow in the winter. Combined with a small dam and open water just downstream from the project, this area serves as a winter roosting habitat for bald eagles. The contract required monitoring of bald eagle behavior during these months. If disturbance was observed, construction work could be suspended for several months.

During the launching process, the tapered launching nose would touch down on top of the landing pier rollers, and then lift the permanent girders upward into position.

Aerial view of the launching process for the Iowa River Bridge.

The sheltered valley was inhabited by Native Americans hundreds of years ago and artifacts and campsites were discovered during the environmental study. The surrounding area also hosts the habitat of the Northern Monkshood plant, a federally protected poisonous herb. As a result, the alignment of the highway was adjusted to avoid interference with these areas.

Construction activities in the ESWZ were specifically defined in the project plans and carefully monitored by bridge engineers and environmental specialists. In addition, IDOT hired an environmental consulting firm to perform on-site inspections weekly. To maintain the natural appearance of the area surrounding the bridge, a total of six construction zones were identified in the plans. Different methods for clearing existing trees and grubbing undergrowth were specified for each zone.

Due to the rigid limitations on any silt leaving the project area and entering the river or the surrounding wetlands, an elaborate network of silt fences (more than ¾ miles overall) was installed prior to construction. To limit potential erosion, crews spread erosion control mulch (created from the few trees cut on site), performed extensive over seeding, and applied multiple layers of straw mesh on steep overlopes. Furthermore, each time a half-inch of rainfall was recorded, another inspection of silt fences was mandated, with repairs or clean out within 12 hours. A remotely accessible weather station helped the inspection team monitor conditions at the site.

IDOT earned the Administrator's Environmental Quality Award from the Federal Highway Administration (FHWA) in September, 2002, for outstanding environmental sensitivity in the planning, design and construction of the bridge. Also cited in the award were Jensen Construction Company, the general contractor, and Jensen's parent company, The Rasmussen Group. FHWA served as technical consultant and helped fund the project.

Teaming for Quality and Solutions

Twenty-eight stakeholders representing 12 different firms and agencies signed a formal partnering agreement prior to the start of the U.S. 20 Iowa River Bridge Project. The purpose: to define the process and channels for problem resolution and reporting of environmental issues that might arise during the project. During construction, a weekly meeting was held at the project site and attended by representatives of IDOT, HNTB, and Jensen Construction as well as the environmental inspectors.

The project proved that teamwork does not develop through the simple act of holding a partnering meeting at the beginning of the effort. Rather, it is an ongoing process whose hallmarks include trust and shared problem-solving. Two critical periods during the project illustrate the benefits of active and ongoing partnering.

The first instance occurred during the drilling of 8-foot diameter shaft foundations, which were approximately 100 feet deep and drilled through the clay overburden into limestone bedrock. During drilling for one foundation, the core barrel tool became lodged in the shaft several feet above final elevation. The compressed construction schedule made it imperative that the foundations be completed on time, requiring that this core barrel be removed quickly. Further challenges resulted when the shaft filled with artesian water flowing in from the surrounding area and the fact that the incident happened during severe winter weather. The project team, working together, secured the services of an experienced deep-water diving team which worked in near zero visibility to cut the core barrel into segments and remove it from the shaft.

The second example occurred when the contractor's jacking and steering systems failed to operate as designed and steel girders drifted away from their intended alignment while launching the bridge toward the first pier. Left uncorrected, the girders would roll far enough off of desired alignment to cause permanent damage. A catastrophic collapse of the cantilever bridge span was also possible at this critical stage in the launching operation.

The project team organized an emergency meeting to determine a course of action: jack the entire girder train up to remove load from the problematic vertical rollers, and provide additional horizontal jacks to push the steel girders transversely to return them to correct alignment. The guide roller units were later modified to permit active control of the girder alignment during future launch operations. The solution fixed the immediate problem, and also provided a means for maintaining alignment for remaining launches.

Standard Setter

The Iowa River Bridge Project spawned a series of inventive solutions to unusual and unexpected construction hurdles when, early in the project, the contractor demonstrated considerable creativity by modifying the original design details and developing specific aspects of the launching system to utilize equipment already owned by the business. A pair of 500-ton capacity hydraulic jacks, originally part of a large drilling rig used to construct foundations for offshore oil platforms, were reengineered to launch the bridge.

In another instance, to prevent intrusion of contaminate-laden runoff from the bridge and approach roadway into the river, a sealed drainage system was installed to collect all storm water landing on the bridge. This water was piped to storage basins on either side of the river where solid material (such as salt and sand) settled and the water returned to the river.

But the sealed drainage system required ingenuity, too, when its large diameter piping wasn't delivered to the job site until after the first launch. The team devised a mobile crane to slowly walk the pipe sections, each weighing more than 8,000 pounds, out to the center of the bridge and maneuver them into their final position. This crane, originally mounted on a truck bed, was modified to ride on a carriage scavenged from the lower unit of two surplus concrete finishing machines.

In the end, the structure was completed without a single significant conflict with the strict environmental controls in place throughout the project. The FHWA Environmental Quality Award celebrated the environmental successes that vaulted the bridge to national prominence as a model for performing essential infrastructure improvements while remaining environmentally sensitive.

Finally, as a result of the team's engineering and environmental achievements, launched steel girder bridge projects in other States have adopted practices emerging from the Iowa River Bridge. The FHWA Accelerated Construction Technology Transfer (ACTT) initiative has identified incremental launching as a preferred method of quickly and safely constructing future bridges. Since completion, IDOT has fielded inquiries from other States eager to learn more about the method. Furthermore, in cooperation with the project partners, IDOT has produced and made available a documentary video, launch monitoring report and a photo library set. The DVD/CD set can be obtained, free of charge, by contacting Ahmad Abu-Hawash at 515 239-1393 (ahmad.abu-hawash@dot.iowa.gov) or Max Grogg at 515 233-7306 (max.grogg@fhwa.dot.gov).

The project team's willingness to take risks has provided 13,000 Iowa motorists a more direct route each day, accomplishing its goals with little or no impact to the beloved natural resources and habitat of the region. FHWA Iowa Division Administrator, Philip Barnes summed it up best by saying, "This was a great Context Sensitive Solution…and most certainly the right project design for this particular site." He also added, "The project continues to generate high interest and it is still collecting awards."